Canada

Energy, Mines and Resources Canada

Énergie, Mines et Ressources Canada

RENEWABLE ENERGY BRANCH

STRATEGIC PLAN FOR BIOENERGY R&D

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SUMMARY

Biomass is an energy resource (bioenergy) that provides Canada with a cost-effective, sustainable, and environmentally acceptable alternative to depleting conventional fossil fuels. Bioenergy currently contributes over 6.5% (approximately 550 PJ/a) of Canada's primary energy supply. Most is obtained from combustion of wood for space heating in the residential sector and for process heating in the forest products industry.

Bioenergy is defined as useful energy derived from biomass; this includes all matter derived directly or indirectly from forest, agricultural and aquatic sources, as well as municipal solid waste and peat. Biomass, by its very nature, is a strategic resource, geographically and chemically. Geographically, it is a land-based resource, available in most regions and provinces of Canada. Chemically, it is extremely versatile in its ability to be transformed into a wide variety of end-uses. Like coal, for example, it can be burned, gasified, liquefied, or partially oxidized to synthesis gas. More advantageous than coal, it can also be directly fractionated to different components or chemicals, or processed into many other energy and non-energy products. Biomass can also be processed into a substitute natural gas (SNG) through chemical or biological action, and it can also substitute for natural gas as a chemical or liquid fuel precursor. Biomass-derived products can also substitute for many fractions of refined petroleum. These versatile characteristics of biomass lend themselves to achieving the practical goal of providing alternative energy forms that can be integrated with conventional energy products immediately, as well as over the long term without major disruptions to current energy-use patterns.

The following strategy for bioenergy R&D responds to Canada's continuing objective of increased energy security in both the short and long term, as well as to a national objective of encouraging economic growth in the energy sector. Successful R&D efforts will provide a technological capability to quickly respond to energy market disruptions, and will offer real, industrial development opportunities for both domestic and export market applications.

SOMMAIRE

Au moment où les combustibles fossiles s'épuisent, la biomasse est une ressource énergétique (la bioénergie) qui donne au Canada une solution de rechange rentable, durable et acceptable au plan de l'environnement. A l'heure actuelle, la bioénergie répond à plus de 6,5 % (environ 550 PJ/an) de la demande en énergie primaire au Canada. La plus grande partie provient de la combustion du bois pour la production de chaleur industrielle dans l'industrie des produits forestiers et le chauffage dans le secteur résidentiel.

La bioénergie se définit comme une énergie utile tirée de la biomasse. Cette dernière comprend toutes les matières provenant directement ou indirectement de la forêt, des exploitations agricoles et de la mer, ainsi que les déchets solides des municipalités et la tourbe. Par sa nature même, la biomasse représente une ressource stratégique, aux plans géographique et chimique. Géographiquement, on la retrouve dans la plupart des régions et des provinces du Canada. Chimiquement, elle est très souple, compte tenu du fait qu'on peut la transformer et l'utiliser à de nombreuses fins. Tout comme le charbon, par exemple, il est possible de la brûler de la gazéifier, de la liquéfier ou de l'oxyder partiellement pour produire un gaz de synthèse. Plus avantageuse que le charbon, on peut aussi la fractionner directement en divers produits chimiques ou composantes ou la transformer en une foule de produits énergétiques ou autres. On peut également tirer de la biomasse un gaz naturel de synthèse (GNS), grâce à un processus chimique ou biologique, ou encore, l'utiliser comme substitut du gaz naturel comme précurseur d'un produit chimique ou d'un combustible liquide. Les produits tirés de la biomasse sont également en mesure de servir de substituts à de nombreux produits du pétrole raffiné. Cette grande souplesse de la biomasse permet de réaliser l'objectif pratique qui consiste à offrir des

sources d'énergie de remplacement pouvant être intégrées de façon immédiate et durable dans les produits énergétiques traditionnels sans trop perturber les habitudes de consommation de l'énergie.

La stratégie de recherche-développement dans le domaine de la bioénergie, que nous exposons ci-après, est conforme à l'objectif du Canada d'accroître la sûreté de l'énergie à court et à long termes, et de favoriser la croissance économique dans le secteur énergétique. Une recherche-développement fructueuse nous donnera la capacité technoloqique de réagir rapidement aux perturbations du marché de l'énergie. Elle offrira des débouchés véritablement favorables à la croissance industrielle en ce qui concerne à la fois les marchés intérieurs et d'exportation.

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INTRODUCTION

It has long been recognized that bioenergy will provide neither an immediate nor universal panacea for a sudden or prolonged oil crisis. Its contribution is expected to be incremental over the short term and, most important, increasing and sustainable into the long term. The depth and scope of its penetration into our energy future depend largely on the future supply price of biomass and the cost of conversion technologies compared with other alternative and conventional energy resources. The bioenergy R&D program outlined below rationalizes a continued effort in technologies where successful results will lead to the development of cost-effective bioenergy supply systems. The resource requirements within each subprogram reflect the level of effort considered necessary to sustain activity in each technology area and which will lead to system cost improvements within a reasonable time frame. They also reflect private sector demand for developing technologies of particular commercial interest.

Some additional advantages of bioenergy systems are embraced by the potential social benefits to Canada because of economic growth and the attendant employment opportunities created, and regional development effects. Particularly attractive is the opportunity that bioenergy systems offer to regions that are economically depressed and that also face chronic unemployment. As well, these are often areas of high energy costs relative to high-density population areas. In addition, since Canada is a world leader in the development of bioenergy systems, but has a smaller domestic marketplace than many other countries, there is a potential for export of technology, process equipment and energy products and byproducts which could provide significant benefits to Canada. The opportunity for incremental commercialization of bioenergy systems is perhaps one of their most attractive features. To paraphrase one of North America's most respected bioenergy thinkers, Dr. E.P. Lipinsky:

> Implementation of most bioenergy ventures is not "lumpy." That is, a large number of small industrial scale bioenergy utility plants each can be built as needed over a period of years. This is well within the financial resources of private companies, utilities and local banks. Financing, construction and final commissioning can often be much easier than building a 1000 MW nuclear facility or a 125,000 barrel per day tar sands plant where delays, cancellations, or withdrawal of venture partners can shake the financial confidence in the project. In short, "land growth matching is easy for bioenergy systems and very difficult for massive systems." (E.P. Lipinsky, Batelle Columbus Institute, U.S.A.).

To ensure a continued and increasing contribution of bioenergy to Canada's energy supply, two major areas of R&D must be addressed, namely, biomass production and conversion. Utilization is possibly a third area, but the objective is to produce energy products that are compatible with conventional energy use systems. Therefore, utilization R&D is not a major thrust of this strategy, with the exception of conversion systems that are intimately associated with utilization such as combustion or gasification, or where other R&D programs are not available to evaluate the quality of a particular product derived from biomass.

Vast quantities of biomass are currently available at competitive costs in the form of wastes generated by industry, primarily the forest product industries, the agrifood sector and municipalities. Major increases in the supply of biomass can be made available in Canada in two ways, namely, modified silvicultural practices and energy plantations. Although for Canada, energy forest plantations may seem to be a vision of the future, a number of pulp and paper oriented experimental/commercial stands of hybrid poplar are already growing in eastern Ontario, Quebec and British Columbia.

On the conversion side, research should maintain an appropriate balance between applied and basic research and development. This balance achieves the objectives of advancing technologies toward demonstration and commercialization, while maintaining a continuity of research so that innovation for the future is encouraged. The range of program sub-activities required includes products in biomass materials handling and storage systems, fuel preparation, and conversion of biomass into energy and industrial chemicals via various thermochemical (combustion, direct liquefaction, gasification) and biological (fermentation) processes.

Bioenergy processing systems offer Canada unique opportunities, although there are a number of problems to overcome. One of the largest problems in implementation is the high risk associated with adopting new technologies. Some bioenergy systems are developed to a point where they are technically feasible, but the capital costs are high relative to oil and gas technologies. This is where R&D plays its most significant role in reducing capital costs and risks.

The various technologies currently being investigated under the federal bioenergy R&D initiatives are outlined in more detail below. Each technology is discussed in terms of perceived opportunity or potential for the technology, the technical barriers impeding the attainment of this potential, the specific objectives for developing the technology, the strategy to accomplish these objectives and, finally, the performers, responsible organizations and resources currently being devoted to the technology area. This bioenergy R&D strategy is considered to represent minimum level of effort to ensure the winding down to a logical conclusion of those areas which are particularly long term in nature, but in which there has already been a significant investment of R&D dollars. It will also continue efforts in those areas having significant energy impacts in the short term, and continued progress in those areas where Canada is at the leading edge in technology development. This level of effort should ensure continued progress towards the fulfillment of EMR's mandate in developing this renewable energy option and the growth of a viable bioenergy industry.

Reactive vs Directed Program Strategy

When EMR initiated the Bioenergy Development Program (BDP) in 1983 as a follow-on to the ENFOR Conversion Program, the latter was essentially reactive to solicited proposals in very general priority areas. As this program evolved and budgets were reduced, it became more directed. More selectivity was applied through processes of narrow selection, sole sourcing, or competitive bids on more precise R&D requirements. In the last two years the BDP has shifted back to a reactive mode in most areas. However, with a much broader information base in bioenergy than say five years ago, the program can be more selective in this reactive mode. Present government policy indicates that BDP should favour those projects where the proponent shares a significant portion of costs, commitment, and risk with the Crown. Therefore, a proposal that is well presented and has significant commercial interest (eg. cost-share by industry) may also be acceptable to the program, though it may not necessarily be specifically reflected in the strategic plan. This strategic plan does, however, allow for these unplanned projects.

TECHNOLOGY DISCIPLINES

PRODUCTION - Biomass Availability

Opportunity

On a national scale it has been estimated that biomass could supply up to 25% of Canada's energy requirements. Resource assessment is required, however, to determine the quantity of biomass available for energy in specific regions in Canada by species and, in the case of forests, tree components. From these data it will be possible to determine how the quantity of available biomass varies with increasing wood utilization patterns and changing harvesting methods. It is important to maintain an up-to-date inventory of these resources so that major land use, municipal, agrifood, or forestry utilization patterns that change drastically in, say, a five year period, are duly noted and utilization strategies modified accordingly. It is worthwhile for inventories of biomass to be accurate, but they need not be precise with the exception of local biomass utilization sites.

Barriers

Although it is known that Canada possesses vast quantities of biomass, accurate information on the location, nature, quantity availability and cost of biomass is required to ensure its effective and efficient utilization for energy.

Changes in inventory occur over time as forests are harvested. Growth and utilization patterns are varied and harvesting techniques change. Not all forest biomass is readily accessible.

Objectives

To wind down major activities in inventory methodology research to a level where they are largely maintenance activities for adjustments and improvements to the inventory, methodology and mathematics.

To concentrate more on localized inventories where energy from biomass projects are contemplated.

Strategy

Close to $5M have been invested to date in establishing a solid biomass resource data base that requires a continuing level of maintenance and updating. Local biomass inventories and related economic assessments should be conducted at sites where energy from biomass projects are being considered. Similarly, a fairly solid data base of peat inventory has been established. Current commitments to peat inventory work should be met and managed down to zero resources. As the long term horizon for peat utilization becomes a short term opportunity, the level of effort in this area would necessarily be increased to gain further accuracy and precision in the inventory. A detailed agrifood resource inventory (predominantly crop, animal and food processing wastes) has been completed, and should provide an adequate data base for the foreseeable future unless agricultural land use practices change radically. Municipal solid and liquid wastes are resources that are already well documented.

Management

Canadian Forestry Service.

Performers

CFS regional laboratories and contractors.

Resources

$200K (from funds provided to CFS by PERD and EMR (NCAEI))

PRODUCTION - Harvesting and Silviculture

Opportunities

In conventional forest harvesting half of the total available biomass is removed for processing into traditional forest products while the remainder of the forest biomass is typically left on the site. These forest residues can increase susceptibility to fires, disease and interfere with reforestation/replanting activities. Removal of this material during harvesting operations would result in better resource utilization and a tremendous increase in biofuel, thereby, substantially increasing the contribution of bioenergy to Canada's primary energy supply.

An economic return may be derived from the utilization for bioenergy of second- and third-growth non-commercial forests which must be removed in land reclamation and forest management schemes necessary to preserve the long term viability of the forest industry.

Since the forestry and agriculture sectors are the primary sources of biomass, the development of a viable biofuel supply industry will provide opportunities for diversification within these sectors.

The development of short rotation, fast growing tree species (eg. hybrid poplars, alders, willows) greatly increases biomass production per hectare of land used. Biotechnology provides a long term opportunity for "engineering" plant biomass through genetic manipulation and tissue culture techniques to provide a variety of energy, plus non-energy, end uses.

Barriers

Poor harvesting techniques which focus solely on the recovery of the commercially exploitable portion of the forest.

Lack of suitable equipment and plantation management techniques capable of recovering biomass in an efficient, cost-effective manner in conjunction with conventional harvesting.

Lack of suitable equipment and plantation techniques for producing biofuel from short rotation, fast growing tree species in an efficient and cost-effective manner.

Lack of a viable biofuel supply industry.

Objectives

To ensure a long term, sustainable supply of low-cost biomass by promoting better and more intensive forest management practices, and developing the concept of forest plantations, energy crops and genetically engineered biofuels.

Strategy

A reduced, but relevant program in silviculture, forest renewal, forest plantations and mechanization should be maintained. Equipment development is very expensive and has already been substantially reduced from earlier levels. Wherever possible, cost-sharing with the private sector will be encouraged or other government technology transfer and development programs used.

Dedicated agricultural energy crops will receive little support beyond current commitments except, in the reactive sense, where the need is strongly indicated by the agrifood sector. Such a need may be indicated for such crops as high fructose sugar yielding Jerusalem Artichoke or saline soil tolerant and high biomass producers such as Kochia.

A relatively new area of research in multiple use crop propagation should continue at modest levels until such time as the forest or agriculture sector concludes either that the increased effort is warranted, or that the potential is nil. Multiple uses might include fiber, food, energy, and chemicals.

Basic research in plant tissue culture is recognized as a potentially important research activity under the biomass production element. However, it is perhaps more appropriate that most of these activities be funded from other sources such as university grants and/or government research laboratories, except where species of special value for energy purposes are involved.

Environmental impact (both positive and negative) such as depletion of soil nutrients, harvesting effects, and impacts of slash removal, is one of the concerns in striving towards better forest management and the more intensive harvesting involved in biomass utilization. This is not a major activity, but will be sustained at a low level. The FORCYTE (FORest nutrient Cycling and Yield Trend and Evaluation) model should continue to be developed and disseminated world wide. Part of the work on FORCYTE model development and application is being carried out under the auspices of the IEA Bioenergy Agreement. This will be continued and if possible expanded, along with a small number of other studies on long term nutrient status of intensively harvested sites.

Canada is a world leader in developing and testing hybrid poplars, a future winner both in terms of productivity and versatility of use. Interest in alder and willow species is also increasing. Therefore, a relatively low level of research activity should be maintained in this area in cooperation with other countries (eg. through IEA). In addition, a limited amount of work will be continued on the modification of conventional silvicultural practices to respond to bioenergy opportunities. Economic assessments of the impact of such modifications on other aspects of forest management will also be carried out.

Management

Canadian Forestry Service.

Performers

CFS regional laboratories and contractors.

Resources

$1.0M per year (from funds provided to CFS by PERD and EMR (NCAEI)).

CONVERSION - Combustion

Opportunity

Significant short term opportunities exist for increasing bioenergy utilization through combustion in the industrial, commercial, and residential sectors. Current estimates indicate that energy generated through biomass combustion could contribute an additional 150 to 200 PJ to Canada's primary energy supply by 1995. In some cases, implementation in these areas has occurred ahead of the technology. That is to say, some equipment already commercialized does not offer desirable levels of performance, efficiency, and emission control.

Implementation of wood burning appliances in the residential sector has preceded the development and adoption of standards for equipment, methods for testing, and optimum design in terms of performance and efficiency. Thus, successful penetration of biomass combustion systems has created problems of smoke and odour nuisance in residential areas as well as an inefficient use of the biomass resource.

Similarly, combustion applications in the forest products industry have been shown to be unacceptable. The current boiler test program has already provided much information for individual boiler operators. In the next year this information will be available for dissemination to the remainder of the forest products industry. This is very important as it is generally recognized that the most readily available increase in bioenergy use will stem from improvements/retrofits of combustion performance in existing industrial boiler equipment. An appropriate strategy for performance improvements and retrofits can be developed once an inventory of existing biomass boilers including those that could be converted to biomass, is established.

It is also recognized that a lack of both industrial and residential wood standards greatly retards commercial development/user acceptance. Once standards have been developed in cooperation with Canadian Standards Association, Underwriters Laboratories of Canada and, perhaps through cooperation with other countries such as the U.S. National Bureau of Standards and SERI in Golden, Colorado, market penetration can proceed more vigorously, and a new series of second generation combustion units will be developed.

Municipal Solid Waste (MSW) is a resource that is currently attracting much attention in North America. A number of municipalities are burning MSW and recovering heat in so-called "energy from waste" projects. Combustion of MSW can alleviate problems of ground water pollution and rapidly increasing costs associated with traditional landfill disposal methods.

Barriers

Lack of standards and their adoption, especially for residential wood burning appliances.

Smoke and odour nuisance from residential wood burning appliances.

Low levels of performance, efficiency, and combustion control in many existing installed industrial units.

Lack of guidelines and information to existing boiler operators on how they can retrofit to biomass or improved performance on their biomass boilers.

Undesirable emissions, through inadequate combustion control might severely constrain further implementation of "energy from waste" combustion systems, especially for municipal solid waste.

Public perception that energy from waste installations pollute the environment and cause odour, noise, etc.. This perception has resulted in the "not in my backyard" or NIMBY syndrome.

Objectives

To develop standards and to encourage their adoption for residential wood heating appliances and industrial systems.

To improve residential wood stove performance and emission control.

To develop methods, equipment, and guidelines for retrofitting existing wood waste industrial boilers.

To assist the industry in developing second generation combustion units having improved performance and reduced emissions.

To evaluate the need for developing combustion systems in the 1-5M BTU/hr capacity for institutional space heating.

To formulate an R&D strategy for MSW combustion (and possibly gasification).

Strategy

For the residential sector, emphasis will be on the development of highly automated, central wood burning systems utilizing wood chips or pellets which are safe, efficient and clean burning. In addition, work will continue on performance monitoring of residential wood burning appliances and the development of test methods with a view to developing safety and emission standards. Standards development should be undertaken in cooperation with the Canadian Standards Association, Underwriters Laboratories of Canada, and the U.S. National Bureau of Standards.

Emission control research will be undertaken as a complementary funding mechanism in conjunction with "environment driven" funding sources.

Information on the results of the boiler test program will be disseminated to boiler operators, manufacturers and the forest products industry in general. In addition, it is highly desirable to compile an inventory of conventional fuel boilers that could be converted to biomass. Data would include such things as numbers available, a measure of difficulty and costs of conversion, cogeneration potential, etc. Guidelines could also be developed for improvements on existing biomass boilers and for retrofits.

Research is to be conducted in Canada and in cooperation with the IEA on the application of pulverized wood in conventional oil boilers.

Novel concepts in boiler automation and chamber design are required to improve boiler efficiency. As well, new applications for biomass fuels such as firing in lime kilns, will be further examined.

With respect to municipal solid waste, there is a need to develop an R&D strategy. Most activities to date in Canada have been demonstration projects using available technology. The current strategy is to collaborate with the U.S.A. and U.K. through an IEA project whereby their experience in R&D in this area would serve as invaluable input into the development of a Canadian strategy.

The adoption of biomass fuels for small-scale combustion systems in the commercial and light industrial sectors requires a concerted effort in the development of cost-effective systems. The establishment of a non-government biomass test facility capable of providing a service to industry or governments who wish to optimize the bioenergy option has been recently initiated. Partially funded through the BDP, this facility will hopefully evolve and develop the capability to perform independent testing of biomass combustion system components, biomass fuel preparation techniques, and classification or specification of biomass fuels according to moisture, size, shape, homogeneity, state of refinement, etc.

A study to evaluate the potential market of combustion units in the 1-5M BTU/hr scale should be conducted, followed by a development program, if desirable.

Management

EMR Bioenergy Division.

Performers

Canadian Combustion Research Laboratory, Contractors: Industry, CSA, ULC, Universities, Provincial Research Organizations (PROs).

Resources

It is expected that due to the economic efficiency of biomass combustion in many applications, the private sector will be highly interested in performing much of this work on a cost shared basis. In that event, significant resources might be directed to biomass combustion, (i.e. as much as $1.0M per year) over the next 2 to 3 years and gradually diminish as industry picks up a greater share of the cost of the activity.

CONVERSION - Gasification

Opportunity

Gasification of biomass for the production of low, medium and high energy gases is on the verge of a technological breakthrough. Gasification offers several advantages over direct combustion of biomass, including: higher temperatures; more efficient and controlled combustion; and lower emissions. The gas produced can be used directly with turbines, diesel and gasoline engines, boilers, and fuel cells, or under particular process conditions as synthesis gas for methanol, ammonia, or FISCHER-TROPSCH synthetic fuel production including gasoline and diesel. A relatively recent opportunity has become apparent in the production of petro-chemical substitutes from gasification or pyrolysis.

Potential applications of gasification technology in Canada appear to be for retrofitting industrial boilers that use oil (with no access to natural gas), for municipal energy from waste projects to provide district space heating for use by industrial complexes, and for applications in remote communities where electrical generation requirements are now met by diesel generators.

The gasification technology, developed through the Biosyn project at St. Juste-de-Bretenières, offers a world-leading technology in fluidized-bed gasification that can be adapted to the production of synthesis gas for methanol production or clean, low-joule gas for other applications, including space heating and industrial diesel engine operation. Alcohol blends with gasoline are being marketed to a limited extent in Canada. Methanol from natural gas is likely to be far less expensive than methanol from biomass or coal into the foreseable future. Significant opportunities exist for exporting the technology to developing countries. Biodev, a sister company of Biosyn, is installing a 6.7 MW electricity generating unit in French Guyana in cooperation with Electricité de France. Biodev estimates a market of over $100M by the year 2000 in developing countries.

Barriers

Low natural gas prices (within Alberta especially) and government assistance programs for the conversion to, and the distribution of, natural gas makes biomass gasification systems uncompetitive in many Canadian markets other than remote communities and at sites where there is very low cost waste biomass available.

Most gasification systems commercially available were designed for homogeneous and consistent feedstocks such as coal rather than for biomass which can vary with type, source, size, moisture content, etc.

Lack of availability of reliable gasification systems in the 3 GJ/hr or smaller range which are highly automated and produce a clean gas.

Objectives

To develop cost-effective, efficient, and instrument controlled gasification systems that can handle a variety of biomass feedstock types and are able to adapt quickly to changing biomass fuel quality.

To develop gasification systems that can produce clean synthesis gas, low-joule gas, or chemicals. (Note: Production of substitute natural gas is a desirable additional capability of a gasification system, but there is no apparent short-to-medium term need for this capability in view of current natural gas reserves.)

Strategy

In support of short term objectives, the production of low-joule gas technologies for application in off-grid industrial installations, remote communities, crop drying, and lime and brick kilns is needed. Emphasis is on the development of reliable systems, particularly smaller systems below 3 GJ/hr, which are highly automated and capable of using a variable quality feedstock.

Synthesis gas production technology could be used in the short term in Canada in a natural gas/biomass hybrid, but this type of application will not be required to any significant extent until the long term. However, since Canada is currently developing leading edge technology in this area, work should continue so that the export potential, especially to lesser developed countries, can be realized. Over the longer term, basic studies on the effects of catalysts on gas quality and second generation gasification techniques such as molten salt gasification, may eventually be evaluated/developed to improve gasification efficiency.

The opportunity for production of chemicals with or without concurrent fuel production will be explored.

Management

EMR Bioenergy Division

Performers

Contractors: Industry, University, PROs.

Resources

One million dollars per year, dropping to approximately $500K, and then increasing gradually if it becomes necessary to scale-up newly developed concepts. Funding requirements at that time would have to be reassessed, in view of projected near term opportunities, or if the export of energy technology becomes more prominent in an energy policy context.

CONVERSION - Liquefaction/Pyrolysis

Opportunity

Research in the direct liquefaction of biomass has not resulted in the rapid commercialization that was promised in the late 1970's. A multinational IEA study conducted by the IEA in 1985 concluded that construction of an international, biomass liquefaction test facility would be premature. The study recognized, however, that processes being developed in Canada are technically more advanced than others around the world. In particular, reference was made to the development of a fluidized-bed process at the University of Waterloo and a vacuum pyrolysis unit at the Université de Laval. The pyrolysis technology has attracted some commercial interest because of its unique capability of biomass (including MSW and scrap tires) conversion and fractionation into useful fuels and chemicals. There has also been recent commercial interest in the University of Waterloo technology.

Another technology system that has attracted commercial interest is a potential hybrid of the Universities of Western Ontario and Waterloo processes. The primary objective will be to produce higher value chemicals as well as fuels.

Canada also has another rather unique approach to biomass liquefaction through prior fractionation of biomass into its three components, followed by the liquefaction of one or more components separately, and using the remaining component(s) on other conversion processes such as hydrolysis/fermentation.

Barriers

It is unlikely that the production of a low grade, heavy type fuel oil from biomass will be competitive as a boiler fuel with petroleum, heavy fuel oil or natural gas in the short term.

There is insufficient scale-up data available on the small (less than 1 kg/hr) systems that have been developed in Canada to date.

Although the potential for fractionation and catalytic upgrading to useful industrial chemicals and even exotic chemicals is acknowledged, this area of research has been, by and large, unexplored.

Objective

To bring certain R&D activities in biomass liquefaction to a logical conclusion, to scale-up and transfer technology developed to the private sector where there is commercial interest, and to further pursue the chemicals production option.

Strategy

It is desirable to wind down certain Canadian direct liquefaction activities in biomass over the next year to ensure that the last eight or more years of research investment will not be lost. Decisions have been made to scale-up at least two processes in cooperation with the private sector where near term commercialization is apparent.

Other existing technology development should continue under a directed program involving the current university performers and a coordinated centralized analysis through B.C. Research and the provision of standard wood samples to all liquefaction researchers. Information exchange among these performers is being facilitated through a closed "computer conference."

Newer emphasis on technology development and research will be placed on the production of higher value chemicals (as well as fuels) and on the novel approach of biomass fractionation followed by liquefaction.

Since Canada does hold the lead in this technology, it would be advisable however, that some level of effort be maintained through grants or contracts to universities so that continuity of expertise and training can be maintained.

Management

EMR Bioenergy Division.

Performers

Contractors: Industry, Universities, PROs.

Resources

$750K per year.

CONVERSION - Ethanol and Other Biochemicals

Opportunity

Biochemical conversion includes the conversion of lignocellulosic substrates to such fuels and chemicals as ethanol, butanol, acetic acid, butanediol, lignin derivatives, furfural, xylitol, phenol, rayon, and other cellulosic polymers, etc.

Fuel ethanol regained importance recently, primarily due to the anticipated near term demand for ethanol (among other alcohols) as a cosolvent for methanol/gasoline blends. Regulated lead phase-down recently announced by Environment Canada to near zero levels of tetra ethyl lead, provides an octane demand gap where alcohols can play a significant role. In a report entitled Alcohol-Additives - A New Opportunity in Transportation Fuels, tabled by the House of Commons Standing Committee on Energy, Mines and Resources, May, 1986, it was recommended that methanol and ethanol be used as blending agents in Canadian gasoline, and that more R&D on ethanol be performed. In a number of technology areas including enzymatic, HF and acid hydrolysis of cellulosics, as well as pentose fermentation, Canada is clearly a world leader. With technology improvements and subsequent cost reduction, it is possible that methanol/ethanol/gasoline blends can be marketed without further subsidy. The estimated market potential for ethanol in such blends is $900M per year by the year 2000. The opportunity for technology export is also well recognized and demonstrated by considerable off-shore commercial interests.

Close behind the recent high-tech boom of the 1970's and 1980's, the biotechnology era is fast approaching. The possible rewards from research and development in this area are vast in scope. Bioenergy production, through Biotechnology, is one important component in this area of opportunity for Canada. Continued R&D to promote the production of fuels and chemicals from biomass through biological processes will spawn additional benefits to Canadian society that are non-energy related.

Pretreatment prior to biological (i.e. enzymatic or direct microbial) conversions, can greatly increase reactivity. Pretreatment and fractionation of biomass components may also make a great deal of technical and economic sense for thermochemical operations as well. For example, steam pretreatment of wood followed by fractionation of cellulose, hemicellulose and lignin could lead to three different operations on the components. The lignin could be liquefied and upgraded to high octane aromatic gasoline components; the hemicellulose could be converted to furfural, dehydrated to animal feed molasses, or fermented to alcohol fuel; and the cellulose preserved as a high grade fibre, converted to a high value cellulose derivative, or further hydrolyzed and fermented to alcohol fuel. Pretreatment methods may include mechanical, thermal/steam, chemical or thermochemical.

Many of the chemicals mentioned above can be derived as co-products of ethanol production. As well, there are many other non-energy petrochemical related co-products of ethanol production, the development of which should be pursued alongside ethanol production so that the entire integrated process developed will eventually become cost-effective and attractive for commercialization. We are reminded that in the early days of petroleum refining, kerosene was the only valuable product. Over the last 100 years, the many fractionated and derived products of petroleum have become some of the most important commodities of modern society.

Barriers

Enzyme production is still the major cost associated with enzymatic hydrolysis and fermentation of lignocellulosics. Although one Canadian company has made exponential progress in improving cellulase enzyme activity, it is still far short of the activity that starch enzymes (amylases) can achieve. Furthermore, the development of lignin and lignin derivatives obtained from enzyme processes has not been sufficient to gain acceptance in the marketplace.

Acid hydrolysis processes have historically been used commercially because they are fast acting. Their disadvantages, however, often include one or more of the following: corrosiveness to most low cost reactor materials; the necessity for neutralization prior to fermentation; the need to acid make-up; the production of very weak ethanol solutions; and up to 50% of fermentable sugars released upon hydrolysis may subsequently be degraded in turn by the acid.

HF hydrolysis holds the promise of near quantitative yields of fermentation sugars at high concentrations. To be cost-effective, the technology must consist of an efficient HF recovery and re-use operation, allow minimal hazards to operational personnel and the environment, and the lignin byproduct should have a higher value than merely its fuel value.

Chemicals such as acetic acid and furfural may be produced as co-products of some of the conversion processes under development, but are in too dilute a form to be economically recovered unless new methods of recovery and concentration are evaluated. Some chemicals obtained as byproducts in the enzymatic hydrolysis/fermentation of ethanol from cellulose such as phenolic resins from lignin will have high value, but limited markets. Therefore, high values assigned to chemical co-products cannot always be assumed to be sustained forever at those values.

The science of pretreatments such as steam explosion is still largely unknown. A clearer understanding of the basic principles could be applied to optimizing pretreatment conditions.

Many biomass conversion processes that have been developed in the past are restricted to certain types of biomass materials. For example, the Madison-Scholler acid percolation hydrolysis is limited to softwood chips. Some pretreatments may make downstream processes feedstock insensitive.

Pentose sugar derived from the hemicellulose component of biomass has been, until very recently, very difficult to ferment efficiently to ethanol.

Fermentation methods need to be improved with better instrumentation and control systems and continuous operation.

Processes should be feedstock insensitive so that process flexibility allows for the use of the least expensive feedstock available at any particular time. For example, a whole corn fodder (i.e. grain, cobs, stockage) might, from time to time, be the least expensive biomass source for a plant primarily designed for wood. Such a biomass conversion plant would have available an even more diverse mix of carbohydrates (sugars, starch, hemicellulose, and cellulose) plus lignin.

Objectives

To develop efficient and cost-effective processes for the production of ethanol from a wide variety of inexpensive biomass sources, and that also optimizes the production of other value added energy and non-energy co-products.

To develop pretreatments that enhance conversion processes or help make them feedstock insensitive.

Strategy

Three technologies, developed or currently under development in Canada, stand out among others, namely, Iotech's enzyme hydrolysis/steam explosion process, St. Lawrence Reactors' acid catalyzed process, and gaseous hydrogen fluoride (HF) hydrolysis.

The enzymatic route offers high yield, a reasonably concentrated sugar solution, a non-corrosive process environment, and the promise of

dramatically reduced capital and operating costs for enzyme production and hydrolysis. It also produces a reactive lignin which may eventually be converted to higher-value products.

The HF process is being developed because it offers the potential for higher yields and ethanol concentrations than even enzymatic hydrolysis can produce. (Note: In enzyme hydrolysis, 10-15% of the input feedstock must be used for enzyme production alone, the remainder is available to be hydrolyzed.) The value of the lignin from this process is not known, and will be evaluated.

Fundamental research and development must be carried out in support of process design improvement and biological reactor development.

Chemicals which may be produced from biomass would be expected to command a higher price in the marketplace than fuels normally do. Therefore, opportunities for chemical production should be researched as a means to improving the economics of biomass conversion systems and also to diversifying the menu of biomass utilization options.

Management

EMR Bioenergy Division.

Performers

Contractors: Industry, Provincial Research Organizations, Universities.

Resources

$2.5M per year.

CONVERSION - Biofuel Preparation and Handling

Opportunity

Biomass materials, by their nature, source and method of collection are extremely diverse, heterogeneous and inconsistent, thereby making them difficult to handle, process, transport and store. Improvements in materials handling, techniques, storage, drying, dewatering, densification and preparation would greatly augment the reliability and level of performance of all biomass conversion operations.

Barriers

The heterogeneous nature of biomass fuels (i.e. high moisture content, low bulk density, etc.) make them difficult to handle, process, transport, convey and store.

Objectives

To improve biomass materials handling systems, storage, dewatering, densification or other means of biomass fuel preparation for conversion.

Strategy

Biomass materials handling, storage, drying, and preparation for conversion or combustion should be maintained at its present level to ensure that short term opportunities for implementation can be exploited without technical constraints.

Reliable biomass feeding systems are essential to almost all biomass conversion systems including combustion units, high pressure gasifiers, liquefaction units, and biological process units. This area must be given significantly more attention than in the past in order to develop necessary continuous, automated feeding systems that are capable of operating reliability with a wide variety of biomass fuels.

Densification of biomass is another area of materials preparation that requires dedicated attention. Densification into pellets or briquettes can facilitate materials handling, storage and especially feeding of conversion units. In addition, if pellets can be made to be water resistant or repellant, outdoor storage could be more easily accommodated. Current levels of support appear to be adequate to address this issue for the time being. Additional projects in this area are not planned until current work in progress is evaluated.

Present commitments to peat processing should be met and future activities be limited to meeting special regional interests such as those in Atlantic Canada. Drainage of peat wetlands for the purpose of forestation is also not a major bioenergy priority. However, peat dewatering and mining techniques in collaboration with IEA peat projects should continue as a long term opportunity.

Management

EMR Bioenergy Division.

Performers

Contractors: Industry, Universities, PROs

Resources

$600K per year.

CONVERSION - Anaerobic Digestion

Opportunity

Among biochemical conversion technologies, anaerobic digestion (i.e. biogas production) has a low funding priority area for EMR since the bulk of scale-up work has already been funded by Agriculture Canada. As well, it is viewed more as an environmental treatment technology than as an energy conversion technology.

Anaerobic digestion is particularly appropriate for use with wet biomass sources such as animal manure, sewage sludges, pulp and paper sludges, aquatic plants or food processing wastes. Other than at municipal water pollution control plants (WPCP's), conventional bulk digestion in Canada has not yet been proven a technical and/or economic success. Most of the R&D to date has been devoted to farm and food processing wastes. The pulp and paper industry has indicated that biogas production could help solve their sludge disposal problems as well as provide an internal energy source.

In recent years, advanced concept reactors have been developed by the National Research Council. These advanced concept reactors, such as fixed-film fermenters, anaerobic filters, fluid-bed and sludge-blanket reactors offer major advantages, including the promise of lower capital costs, the low requirement for maintenance and supervision, fast reaction time in large volumes, and most importantly, extreme stability and insensitivity to changes in loading rate or loading material type.

Anaerobic digestion for the production of energy offers other benefits to society. As mentioned above, in terms of environmental benefits, it is an extremely effective method of reducing biological oxygen demand. In the past, however, conventional technology has not been a preferred method of treating secondary sludge because of its high capital cost, low throughput and instability. For example, when a conventional bulk digester fails, it can often take two months to reactivate the process and bring it back to normal operating capacity.

A second and more recently acknowledged benefit of anaerobic digestion is the production of relatively pathogen free high protein feed for animals. This has been demonstrated through research and development at a farm in southwestern Ontario. In addition, the sludge from anaerobic digestion has been well documented as a stabilized fertilizer for land application that has retained all of its original soil nutrients as well as reduction in volume and odour.

Barriers

High retention times, reliability problems, and instability leading to digester failure have been the major cost and technical problems of conventional digestion technology. Although these problems have been greatly overcome in the laboratory, cost-effective scale-up of these advanced concept reactors has not been apparent.

Objectives

To monitor improved conventional and advanced concepts for anaerobic digestion that are currently established as pilot plants and demonstrations on farms and food processing plants.

To determine the cost of advanced concept systems.

To determine the feasibility and market potential of anaerobic digestion applications in the pulp and paper industry and develop systems accordingly, if required.

Strategy

The development and demonstration activities of advanced concept reactors were, until recently, sustained at a high level of support during completion of various pilot plant facilities. Program efforts are currently primarily focussed on monitoring, evaluation, and problem solving with existing digesters. Other than this activity, digestion research will return to pre-1981 levels of effort.

Past experience has shown us, however, that flexibility and the reactive nature of a federal bioenergy plan should allow for the contingency that high-cost development activity in support of demonstration of commercial projects, or even other improved technology concepts (should this be the case) may require an increased level of support.

The reactive nature has, in fact, allowed a change in strategic plan from two years ago whereby the pulp and paper industry has indicated that a revived effort in biogas R&D and application should be directed towards their problems, particularly with respect to CTMP/TMP wastes. This effort is now being initiated, and if shown to be feasible, could expand significantly.

Management

EMR, Bioenergy Division in cooperation with NRC, Agriculture Canada and Environment Canada.

Performers

Contractors: Industry, PROs.

Resources

$300K per year.